



Laser Science & Technology

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UCRL-TB-136126-03-5

Large-Aperture Reactive Ion Beam Etcher (RIBE) Operational for Fabrication of Meter-Scale Gratings for HEPW Lasers

To enable high-energy petawatt (HEPW) laser operation on NIF, LS&T is developing high-energy, short-pulse gratings and focusing optics for the back-end system. Since the laser pulse is shortest and irradiance is highest on the final grating and focusing optic, the output of future HEPW lasers will be limited by the damage threshold of these components. Current design for generating 5-kJ, 10-ps laser pulses on NIF call for gratings almost 2 m in long aperture to optimize NIF HEPW system performance.

The researchers in the Diffractive Optics Group are currently developing high-damage-resistance, large-aperture multilayer dielectric reflection gratings for compression of the amplified pulses. Initial tests indicate that multilayer dielectric (MLD) coated gratings etched into a SiO_2 layer hold the promise for high-fluence operation in NIF HEPW.

A large-aperture reactive ion mill has been built and activated to etch submicron-pitch grating structures into meter-scale substrates. Figure 1 shows the machine with the crew responsible for putting it together. MLD gratings as large as 2000×800 mm in area can be fabricated. The heart of the system

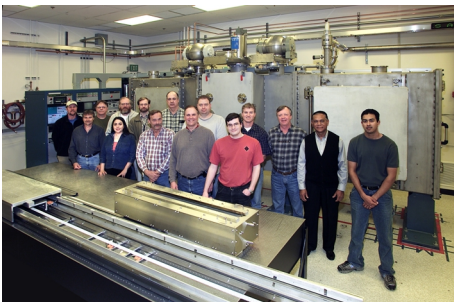


Figure 1. The reactive ion mill (foreground), the vacuum chamber (background), and the RIBE team members. From left to right, front row: Jerry Britten, Lori Risinger, Jim Peterson, Kent Farmer, James Nissen. Back row: Mike Aasen, Carly Hoaglan, Glenn Beer, Chris Barty, Les Jones, Jim Ferguson, Tom Carlson, John Laycak, Manny Carrillo, A. C. Iyer. Not pictured, Jim Colton, Dennis Coutts, Steve Mills.

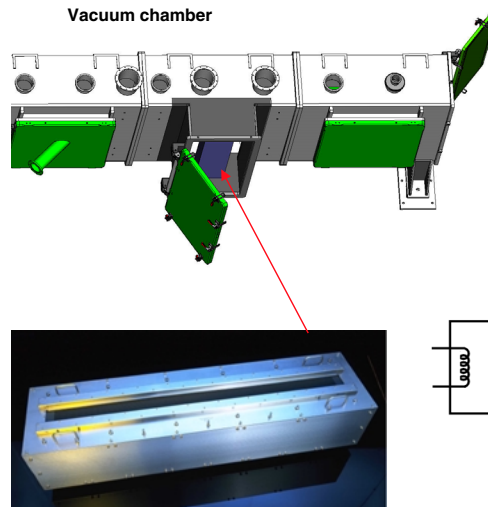


Figure 2. Schematic of the ion beam etcher.

is a commercial RF-powered ion source that emits a collimated beam of ions 6 cm wide by 110 cm long. We use a blend of chemicals (consisting of Freon compounds, argon, and oxygen) to generate reactive fluorine atoms, ions, and free radicals, which selectively etch oxide materials through the photoresist mask to create grating structures over large multilayer-coated substrates.

The etcher is approximately 18 ft long, 8 ft tall, and 3 ft wide. The ion source is mounted vertically in the center chamber. A linear stage translates the patterned substrate back and forth across the ion beam, with each pass removing a small amount of material. Figure 2 shows a schematic of the ion beam etcher. Vacuum level in the chamber is typically 2×10^{-4} Torr during processing.

The reflection gratings developed for HEPW (Figure 3) are composed of two functioning structures: a multilayer stack of dielectric oxides that provide reflectivity at wavelength and angle of use and a SiO_2 grating layer with width and height of grooves designed for maximum efficiency. The key to high-damage-fluence MLD gratings is minimizing the E-field enhancement at groove surface. We are currently damage testing sample gratings to

verify the NIF HEPW design. This new tool will be integrated with our existing holographic exposure, chemical processing and metrology equipment to fabricate meter-scale gratings.

Near-term work will focus on optimization of process parameters to etch SiO_2 and Ta_2O_5 oxide layers, and to remove photoresist with oxygen RIBE. The ultimate goal is to fabricate the world's largest multilayer dielectric gratings to field HEPW laser beams on NIF for stockpile stewardship, fast-ignition fusion, and extreme-field science experiments.

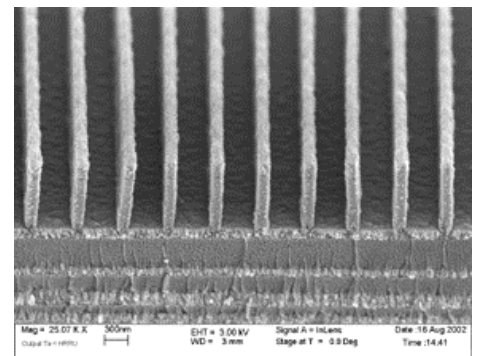


Figure 3. Microstructure of a multilayer dielectric grating. Grating lines 150 nm wide, 600 nm tall on 555 nm centers etched into SiO_2 layer atop a multilayer structure of Ta_2O_5 , SiO_2 , and Al_2O_3 .

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This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.